First Hit   Fwd Refs

L8: Entry 4 of 22   File: USPT   Jan 15, 2002

DOCUMENT-IDENTIFIER: US 6339612 B1
TITLE: Method and apparatus for joint detection of data in a direct sequence spread spectrum communications system

Abstract Text (1):
Joint detection of data signals occurs in a code division, multiple access (CDMA) communication system as follows: A digital signal processor (315) first extracts a midamble portion of transmitted signal vectors and generates an estimate of the channel response corresponding to each user-antenna pair using a channel estimator (401). In the preferred embodiment, each user's transmission within the communication system comprises either the type-1 or type-2 burst with varying midamble and guard period durations. Next, a convolution processor (402) forms the convolution of the user signature sequence with the channel impulse response estimate associated with each user and each of the antennas (308)-(310). A detector (403) utilizes the set of vectors and creates a set of sub-system matrices and solves the sub-system matrices to extract symbol information from an individual remote unit's transmission. Finally, the detector (403) outputs symbol information for subsequent infrastructure processing.

Application Filing Date (1):
19980209

Brief Summary Text (4):
Since the early 1990's, code division, multiple access (CDMA) cellular communications systems have been designed based on direct-sequence spread-spectrum (DS-SS) principles. In such systems, multiple users simultaneously occupy the same radio frequency channel, separated only by user-specific spreading or signature sequences. Probably the best known contemporary example of this approach to cellular system design is that defined by Personal Station-Base Station Compatibility Requirements for 1.8 to 2.0 GHz CDMA Personal Communication Systems" (American National Standards Institute (ANSI) J-STD-008), or, broadly equivalently, the Telecommunications Industry Association Interim Standard 95 (TIA IS-95).

Brief Summary Text (5):
Recently, proposals for so-called "3-rd Generation" cellular communication systems have been made to the European Telecommunications Standards Institute (ETSI) for adoption within the Universal Mobile Telecommunications System (UMTS) standardization process. Among the proposals are systems based on Direct-Sequence, Spread-Spectrum (DS-SS) technology. One such candidate system, which is particularly relevant to the present invention, is usually referred to in the UMTS community as the TD-CDMA system (for "Time-Division Code-Division Multiple Access"). That system makes use of a combination of time- and code-division techniques as a means of improving overall system capacity while purportedly retaining compatibility with 2.sup.nd Generation systems, notably the Group Special Mobile (GSM) cellular communications system.

Brief Summary Text (6):
As can be seen from FIG. 1, the TD-CDMA air interface incorporates both TDMA and CDMA elements. The TDMA component is provided by dividing each radio frequency

h   e b   b g ee e f   e   b   b c e

channel into frames of 4.615 ms duration, with each frame further divided into time slots of approximately 577 us in length. The CDMA element is permitted by the allocation to each user of a unique 16-ary Walsh-Hadamard orthogonal spreading code which is used to spread the Quadrature Phase Shift Keyed (QPSK) or Quadrature Amplitude Modulation (16-QAM) data symbol sequences comprising the useful part of each user's transmission.

Brief Summary Text (7):
The mobile station (MS) or base station (BS) transmission within any timeslot is referred to a `burst`. As presently envisaged, the TD-CDMA air interface supports two distinct burst types, the general structure of which is shown in FIG. 1. The so-called type-1 burst transmits a data sub-burst of 28 data symbols, followed by a midamble of length 296 chips (used for channel estimation purposes), a second sub-burst of 28 data symbols, and finally a guard period of 58 chips; the type-2 burst transmits 34 symbols in each sub-burst, with midamble and guard period durations of 107 and 55 chips respectively. In both cases the length of each burst is 1250 chips. The same burst structures are used for both forward and reverse links, although since the forward link represents a point-multipoint transmission, the content of the midamble segment is slightly different in that case. This is of no consequence, however, for the present purposes. Accordingly, the description of the drawings below will focus on reverse link operation, pointing out differences between the forward and reverse only when these are significant for the description of the invention.

Brief Summary Text (8):
FIG. 2 shows a communication system employing a TD-CDMA air interface. A single timeslot is shown by the figure, within which K mobile stations 201-209 are simultaneously active. In the example shown, the mobile station population 201-209 transmits simultaneously on a specific timeslot, distinguished by length-16 spreading codes c.sup.(1) through c.sup.(k) respectively. It is important to note that--unlike IS-95 systems in which the sequence used to spread each symbol is a sub-sequence of a much longer sequence--the same code c.sup.(k) is used continuously to spread each data symbol from the same user. In other words, the received signal at BS 200 comprises a plurality of time overlapping coded signals from individual mobile stations, each transmitted within the same timeslot and distinguishable by a specific signature sequence.

Brief Summary Text (9):
The use of conventional DS-SS receivers such as the RAKE receiver is not, however, envisaged for use in the TD-CDMA system. Rather, receiver designs capable of simultaneously or jointly recovering the data symbols transmitted by the population of mobile stations operating within the same timeslott frequency within a given cell or sector are intended. Examples of such receivers are described in articles Lupas R., Verdu S., "Linear Multiuser Detectors for Synchronous Code-Division Multiple-Access Channels", IEEE Trans. Inf. Theory, vol. 35, no. 1, January 1989, Klein A., Baler P. W., "Linear Unbiased Data Estimation in Mobile Radio Systems Applying CDMA", IEEE J. Sel. Areas Comm., vol. 11, no. 7, September 1993, Blanz J., Klein A., Nashan M., Steil A., "Performance of a Cellular Hybrid C/TDMA Mobile Radio System Applying Joint Detection and Coherent Receiver Antenna Diversity", IEEE J, Sel. Areas Comm., vol. 12. No. 4, May 1994, and Jung P., "Joint Detection with Coherent Receiver Antenna Diversity in CDMA Mobile Radio Systems", IEEE Trans. Veh. Tech., vol. 44, no. 1, February 1995.

Drawing Description Text (2):
FIG. 1 illustrates a prior-art Time-division, Code-division Multiple Access (TD-CDMA) air interface incorporating both Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA) elements.

Drawing Description Text (3):
FIG. 2 is a block diagram of a communication system utilizing the TD-CDMA air

h   e b   b g ee e f   e   b   b c e

interface of FIG. 1 for a single timeslot.

Drawing Description Text (4):
FIG. 3 is a block diagram of a mobile station and base station illustrating transmission and reception of signals in the TD-CDMA communication system of FIG. 2 in accordance with the preferred embodiment of the present invention.

Detailed Description Text (2):
Although the following description relates to the candidate UMTS TD-CDMA system, it will be readily appreciated that the invention may apply to any CDMA system in which the signature sequences assigned to each user do not change from symbol to symbol over some fixed interval of time, and where some means of channel estimation are provided. For the particular TD-CDMA example, the interval is the burst (or more precisely, the sub-burst) and the midamble provides the means of channel estimation.

Detailed Description Text (3):
Joint detection of data signals according to the invention in such a CDMA communication system proceeds generally as follows. A digital signal processor (DSP) first extracts the midamble portion of the burst (FIG. 1) received on each antenna and generates, using the channel estimation function, an estimate of the complex-valued channel impulse response defined from each user to each antenna. Next, the DSP forms the convolution of the assigned user signature sequences with the channel impulse response estimate associated with each user and each antenna. A detector, as described by the detailed description of the invention below, then utilizes the resulting set of convolved signal vectors to create a system of sub-matrices and then solves that system of sub-matrices in order to extract the underlying modulated data symbol information from each user. The detector outputs soft-decision symbol information for use in subsequent error control decoding. Unlike prior-art detectors, creating the system of sub-matrices to extract the data symbol soft decision information results in less computational complexity than the direct approaches of the references mentioned above, resulting in receivers which are less costly and consume lower amounts of power compared to the prior-art joint detection receivers.

Detailed Description Text (8):
In the preferred embodiment of the present invention mobile station transmit timing correction (similar to that employed in the GSM cellular communication system) is employed for the reverse link of the TD-CDMA system such that the bursts of the K simultaneously active users are observed quasi-synchronously at the BS receiver. That is, the bursts are received at the BS receiver aligned in time except for a timing error of the order of a fraction of the symbol duration T.sub.s, or equivalently of the order of a few chips duration.

Detailed Description Text (11):
DSP 320 first extracts the midamble portion of the received signal vectors s.sup. (ka) and generates an estimate within channel estimator 401 of the channel h.sup. (k,ka) (t,.tau.) corresponding to each user-antenna pair by making use of the known midamble sequence m (see FIG. 1). This operation may be done using a variety of known channel estimation methods, including matched filtering, or periodic inverse filtering such as the approach described in Steiner B., Jung P., "Optimum and Sub-optimum Channel Estimation for the Uplink of CDMA Mobile Radio Systems with Joint Detection", by European Trans. Telecom., vol. 5, January-February 1994. The output of the channel estimator 401 is a set of K.K.sub.a channel impulse response estimates, available at T.sub.c -spacing, of length-W and represented by the vectors:

Detailed Description Text (17):
where the complex data symbols are taken from an M-ary alphabet V={.nu..sub.1, .nu..sub.2, . . . , .nu..sub.M }. Any alphabet may be used in theory, although in

h   e b   b g ee e f   e   b   b c e

practice the TD-CDMA system proposes 4-ary (QPSK) or rectangular 16-ary (16-QAM) alphabets. Introducing a transmitted symbol vector as

Detailed Description Text (29):
With a total of K.sub.a antennas, an overall, concatenated signal <u>observation can be denoted by the vector</u> e,

Detailed Description Text (90):
The descriptions of the invention, the specific details, and the drawings mentioned above, are not meant to limit the scope of the present invention. For example, although the above description was in the context of a reverse link, the invention may be applied equally to both forward and reverse links. Additionally, the above discussion referred to a generic burst structure comprising two distinct blocks of data symbols. Clearly both type-1 and type-2 TD-CDMA burst types are within the scope of the above discussion. Additionally, in order to support higher data rate services, it has been proposed that a single user may transmit on more than one timeslot with a frame, or may transmit more than one data symbol sequences (requiring more than a single spreading code to be allocated to that user). Nevertheless, it is intended that the present invention encompass any data symbol sequence that may be utilized. It is the intent of the inventors that various modifications can be made to the present invention without varying from the spirit and scope of the invention, and it is intended that all such modifications come within the scope of the following claims.

Other Reference Publication (1):
Blanz, et al., Multi-User Direction of Arrival and Channel Estimation for Time-Slotted CDMA with Joint Detection, IEEE, DSP 97, p. 375-378, Jun. 1997.*

Other Reference Publication (4):
Klein A., Baier P.W., "Linear Unbiased Data Estimation in Mobile Radio Systems Applying CDMA", IEEE J. Sel. Areas Comm., vol. 11, No. 7, Sep. 1993.

Other Reference Publication (6):
Jung P., "Joint Detection with Coherent Receiver Antenna Diversity in CDMA Mobile Radio Systems", IEEE Trans. Veh. Tech., vol. 44, No. 1, Feb. 1995.

Other Reference Publication (7):
Steiner B., Jung P., "Optimum and Sub-optimum Channel Estimation for the Uplink of CDMA Mobile Radio Systems with Joint Detection", by European Trans. Telecom., vol. 5, Jan.-Feb. 1994.

CLAIMS:

1. An apparatus for detection of data signals from a transmitted signal in a Time-Division, Code-Division Multiple Access (TD-CDMA) communication system, the transmitted signal comprising a plurality of time overlapping coded signals transmitted from individual remote units, each coded signal transmitted within the same timeslot and distinguishable only by a specific encoding, the apparatus comprising:

a channel estimator having the transmitted signal as an input and outputting a midamble portion of the transmitted signal;

a convolutional coder having the midamble portion of the transmitted signal as an input and outputting a set of vectors representative of the transmitted signal; and

a decoder having the set of vectors as an input and outputting symbol information for an individual remote unit's transmission, the symbol information being a solution to a set of sub-system matrices derived from a system matrix via a

h   e b   b g ee e f   e   b   b c e

recursive procedure, wherein the recursive procedure propagates estimated data symbols in only the forward or both the forward and backward directions as a means of refining the symbol information;

wherein the system matrix is represented by the equation ##EQU30##

wherein u.sub.n is a vector comprising the received signals and some prior estimated data symbols A.sub.1 and A.sub.B,1 is are subsystem matrices, w.sub.n is noise, and d.sub.n are data symbols to be estimated.

2. In a communication system utilizing Direct-Sequence, Spread-Spectrum (DS-SS) techniques for the transmission of signals, a method for determining an individual user's transmitted data from a received signal, the method comprising the steps of:

representing the received signal as a system matrix, wherein the system matrix is represented by the equation ##EQU31##

wherein u.sub.n is a vector comprising the received signals and some prior estimated data symbols A.sub.1 and A.sub.B,1 is are subsystem matrices, w.sub.n is noise, and d.sub.n are data symbols to be estimated;

partitioning the system matrix into sub-matrices to form a plurality of sub-system matrices;

solving the plurality of sub-system matrices via a recursive forward or forward-backward procedure to determine the individual user's data from the transmitted signal; and

transmitting the individual user's data to infrastructure equipment for further processing of the user's data.

3. In a Time-Division, Code-Division Multiple Access (TD-CDMA) communication system, where a transmitted signal comprises a plurality of time overlapping coded signals transmitted from individual remote units, each coded signal transmitted within a same timeslot and distinguishable only by a specific encoding, a method for determining an individual user's transmitted data from a received signal, the method comprising the steps of:

extracting a midamble portion of the transmitted signal;

convolutionally encoding the midamble portion of the transmitted signal to produce a set of vectors representative of the transmitted signal;

representing the convolutionally encoded midamble portion of the transmitted signal as a system matrix wherein the system matrix is represented by the equation ##EQU32##

wherein u.sub.n is a vector comprising the received signals and some prior estimated data symbols A.sub.1 and A.sub.B,1 is are subsystem matrices, w.sub.n is noise, and d.sub.n are data symbols to be estimated;

partitioning the system matrix into sub-matrices forming a plurality of sub-system matrices;

solving the plurality of sub-system matrices via a recursive forward or forward-backward procedure to determine the individual user's data from the transmitted signal; and

transmitting the individual user's data to infrastructure equipment for further

h   e b   b g ee e f   e   b   b c e

processing of the user's data.

h   e b   b g ee e f   e   b   b c e